Highly Vibrationally Excited OH in the Terrestrial Mesosphere: Key Rate Constants for OH(v = 9, 8) Removal by Atomic and Molecular Oxygen Required for TIMED/SABER Observations

Completed Technology Project (2017 - 2020)

Project Introduction

SRI International proposes laboratory measurements of the rate constants for: 1) the total removal of OH(v = 9) and OH(v = 8) by O atoms and O2 molecules and 2) the single-quantum relaxation of OH(v = 9) to generate OH(v = 8) in collisions with O atoms and O2 molecules. The experiments will also determine the temperature dependence of these rate constants in the range 150-300 K, so that the rate constant data can be directly applicable to the mesospheric OH nightglow region. These measurements are critical for a reliable analysis of the OH(high v) Meinel band emission measurements of the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument aboard NASA’s Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. Although the hydroxyl radical is a key player in the chemistry and energy balance of the middle terrestrial atmosphere and several studies have investigated energy transfer processes between OH(v) and atmospheric molecules, several gaps exist in our understanding of its interactions with oxygen atoms and molecules, the two most important atmospheric species responsible for OH(high v) collisional relaxation. None of the six aforementioned key rate constants has been measured at temperatures relevant to the mesosphere. Three of those rate constants have only been measured at room temperature and for the remaining three, i.e., the total removal rate constant for OH(v = 8) + O and the rate constants for OH(v = 9) + O2 and OH(v = 9) + O single-quantum relaxation to generate OH(v = 8), there have never been any laboratory measurements. We have developed laser-based experimental approaches to measure the vibrational level dependence of the collisional removal rate constants for collisions of OH(v) with atmospherically relevant colliders. Research in our laboratory has provided the first experimental measurements on the interaction of OH(v = 9) with O and N2 at room temperature. These experiments demonstrated that the total removal rate constant for OH(v = 9) + O at room temperature is significantly larger than those for removal by O2 and N2. A physical explanation of this rather unexpected result remained elusive for almost a decade. In a breakthrough development, our most recent studies provided the first laboratory demonstration of the existence of new rapid, multi-quantum vibrational-to-electronic relaxation pathways applicable to OH(high v) + O collisions. We plan to use a combination of laser-based experimental approaches we have previously developed in our laboratory to study the aforementioned critical six rate constants. SRI International is an ideally suitable setting to perform the proposed work given our history in the invention and design of experimental approaches to study these complex collisional energy transfer processes. Moreover, we will work with Dr. Martin Mlynczak, a member of the TIMED/SABER Team, who will oversee the implementation of our experimental results into the SABER data analysis and modeling. Accurate values of the deactivation rate of the high-v states of OH are necessary for proper interpretation of the SABER data from the TIMED satellite and their availability would be most beneficial as soon as practically

Image Not Available

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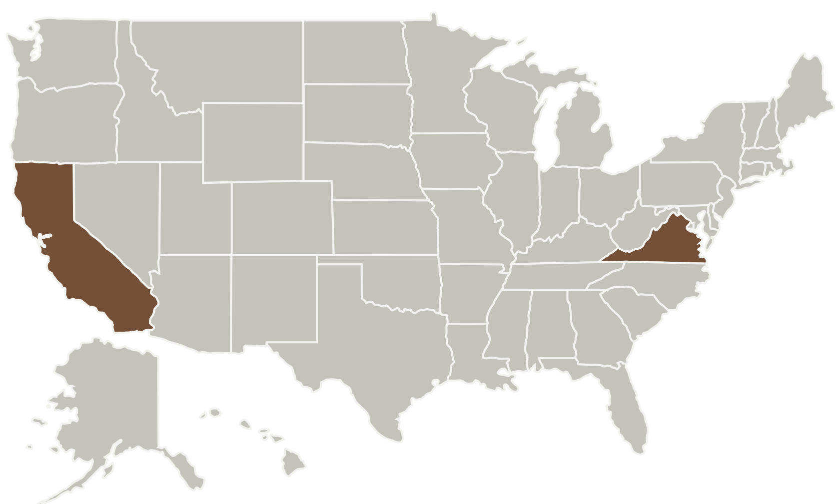
possible given the advanced stage in the life cycle of NASA's TIMED mission. In addition, these rate constant values are essential for computing the heating efficiency of the highly exothermic H + O3 reaction, a key factor included in photochemical models of the upper atmosphere. The proposed research fits well within the Laboratory Nuclear, Atomic and Plasma Physics (LNAPP) sub-element of the NASA Heliophysics Technology and Instrument Development for Science (H-TIDeS) Program because these results on photochemical kinetics and dynamics are needed in atmospheric models and address the goals of the Decadal Heliophysics Survey.

Anticipated Benefits

Support NASA's strategic objectives to understand the Sun and its interactions with Earth and the solar system, including space weather. This will be achieved by developing/demonstrating instrumentation technology necessary to address the following science goals:

- Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system;
- Advance our understanding of the connections that link the Sun, the Earth, planetary space environments, and the outer reaches of our solar system;
- Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

SRI International

Responsible Program:

Heliophysics Technology and Instrument Development for Science

Project Management

Program Director:

Roshanak Hakimzadeh

Program Manager:

Roshanak Hakimzadeh

Principal Investigator:

Konstantinos Kalogerakis

Co-Investigators:

Lori L Mazzei
Martin G Mlynczak

Heliophysics Technology And Instrument Development For Science

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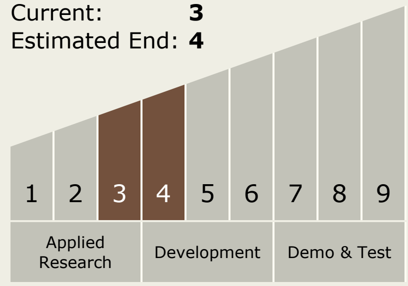
Organizations Performing Work	Role	Type	Location
SRI International	Lead Organization	Industry	Menlo Park, California

Primary U.S. Work Locations	
California	Virginia

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └─ TX08.1 Remote Sensing Instruments/Sensors
    └─ TX08.1.3 Optical Components

Target Destination

The Sun